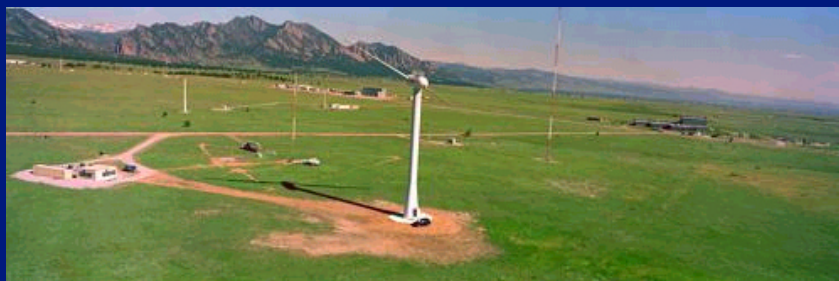


Interconnection of Distributed Wind Energy Systems

December 2001
Ed Cannon, D.E., P.E.



Power Quality of Distributed Wind Projects in the Turbine Verification Program

J. Green, J. VandenBosche, T.
Lettenmaier, G. Randall, T. Wind

Recently presented to
UWIG/TVP Technical Workshop
November 13-14

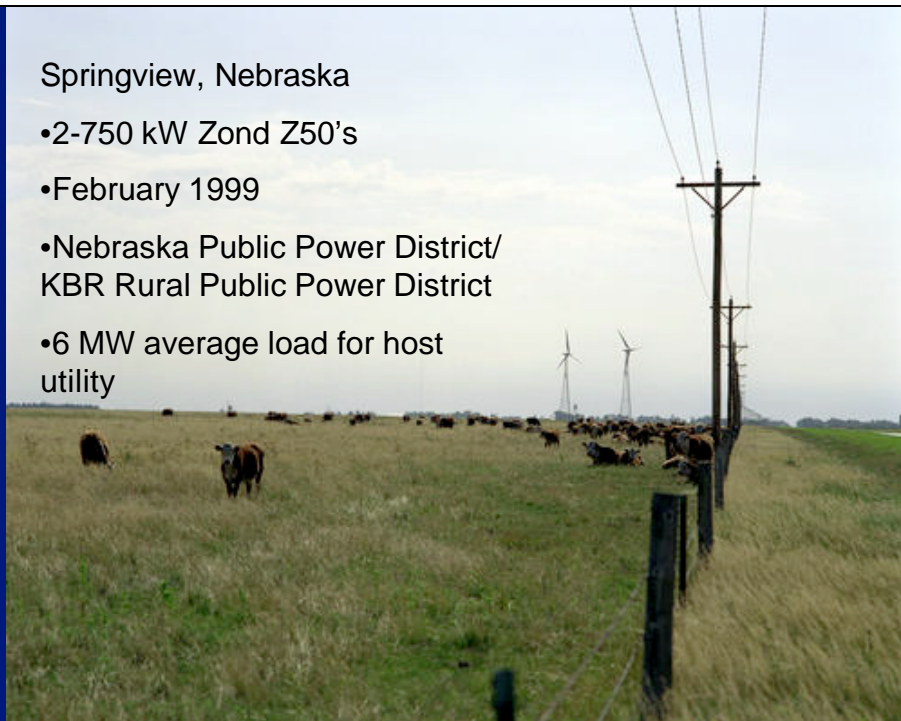


Algona, Iowa

- 3-750 kW Zond Z50's
- December 1998
- Cedar Falls Utilities/
Algona Municipal Util.
- 11 MW average load
for host utility

Springview, Nebraska

- 2-750 kW Zond Z50's
- February 1999
- Nebraska Public Power District/
KBR Rural Public Power District
- 6 MW average load for host
utility





Glenmore, Wisconsin

- 2-600 kW Tacke TW-600e's

- March 1998

- Wisconsin Public Service Corporation

- 1,600 MW average load for host utility



Kotzebue, Alaska

- 10-65 kW AOC 15-50's

- September 1997/June 1999

- Kotzebue Electric Association

- 2.5 MW average load for host utility



TVP Distributed Wind Projects: Wind Turbines

Project	Algona, Iowa	Springview, Nebraska	Glenmore, Wisconsin	Kotzebue, Alaska
Number of turbines	3	2	2	10
Rated power - per turbine	750 kW	750 kW	600 kW	66 kW
Turbine model	Zond Z50	Zond Z50	Tacke TW-600e	AOC 15/50
Generator	Wound rotor induction	Wound rotor induction	Squirrel cage induction (4/6 pole switchable)	Squirrel cage induction
Frequency converter	PWM inverter	PWM inverter	None	None
Control method	Variable speed; pitch control	Variable speed; pitch control	Two speeds; stall control	Fixed speed; stall control
Power factor correction	Power electronic Winter: PF=.93 Summer: PF=.90	Power electronic PF = 1.0	Switched capacitors	Fixed capacitors

TVP Distributed Wind Projects: Feeders & Substations

Project	Algona, Iowa	Springview, Nebraska	Glenmore, Wisconsin	Kotzebue, Alaska
Rated power - project	2,250 kW	1,500 kW	1,200 kW	660 kW
Distribution voltage	13.8 kV	12.5 kV	24.9 kV	12.5 kV
Distance to substation	6 miles	1 mile	6 miles	5 miles
Feeder miles beyond turbines	0	200 miles	6 miles	0
Feeder Maximum Load	1,000 kW	Not available	8,700 kW	300 kW
Substation Minimum Load	2,000 kW	Not available	2,700 kW	1,800 kW

Pending IEC Standard 61400-21

“Measurement and Assessment of Power Quality Characteristics of Grid Connected Wind Turbines”

- Maximum Power - 60-sec and 0.2 sec averages
- Reactive Power - as function of output power level
- Voltage Fluctuations (flicker) - flicker coefficients for continuous operation at 4 wind speeds, and for switching events
- Harmonics - total and by harmonic frequency

Additional parameter for this study:

- Feeder Voltage Regulation



Power Quality Standards

Sources for limits on power quality:

- IEEE 519 for current harmonic distortion limits
- ANSI C84.1 for feeder voltage regulation
- (IEC 1000-4-15 and IEC 1000-3-7 for flicker)



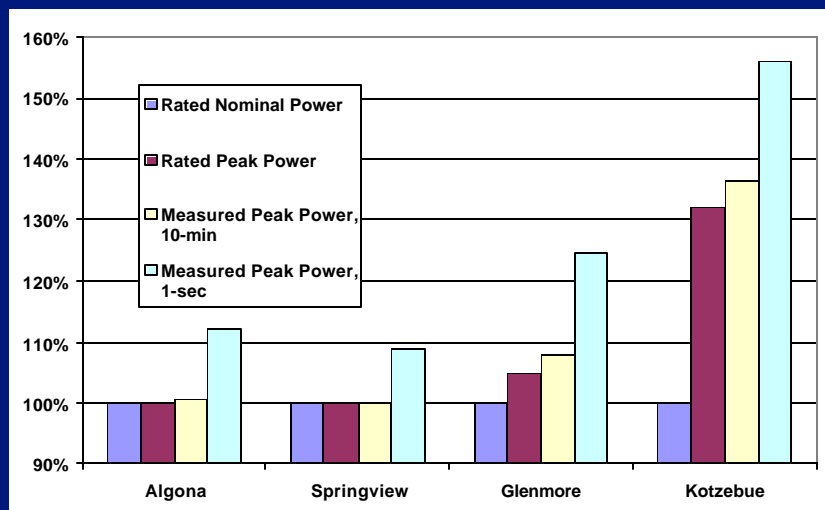
TVP Distributed Wind Projects: Available Data

Data acquired using Second Wind Phaser power transducers:

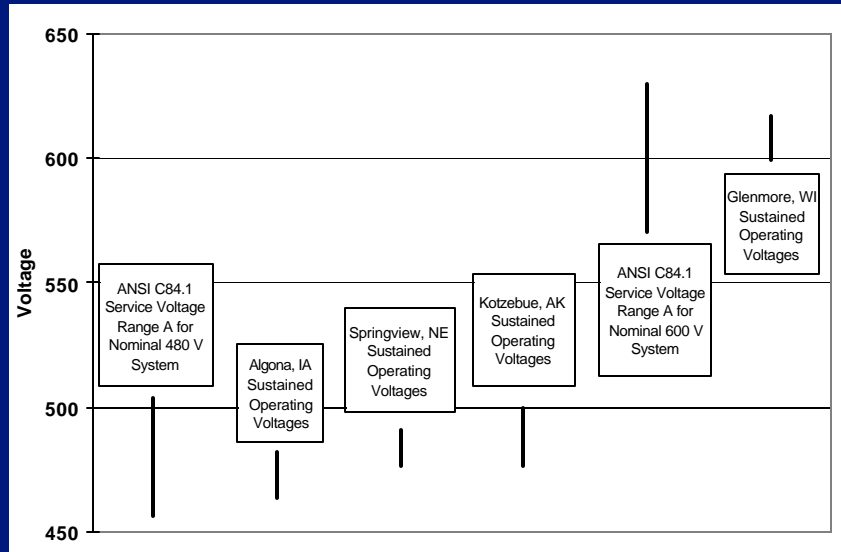
- 10-min average, maximums, and minimums
- 2 weeks of data (2 months for Kotzebue)
- Data not adequate for flicker measurement



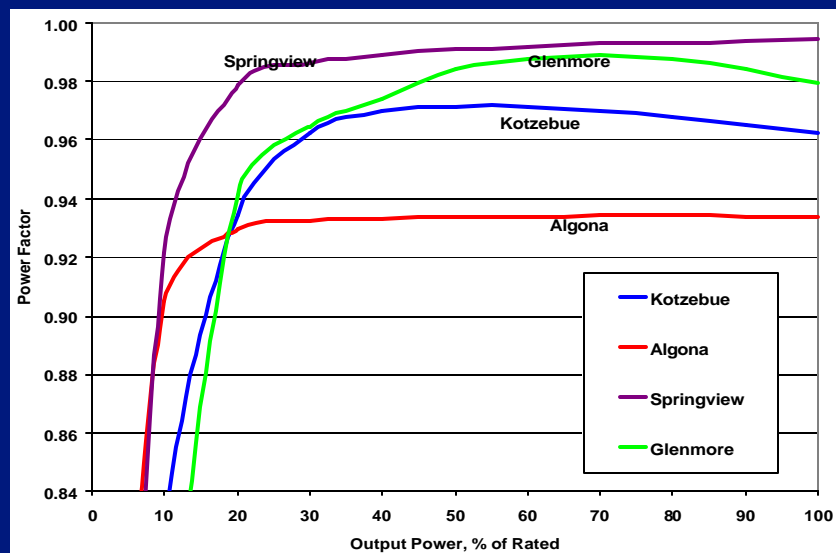
Peak Power



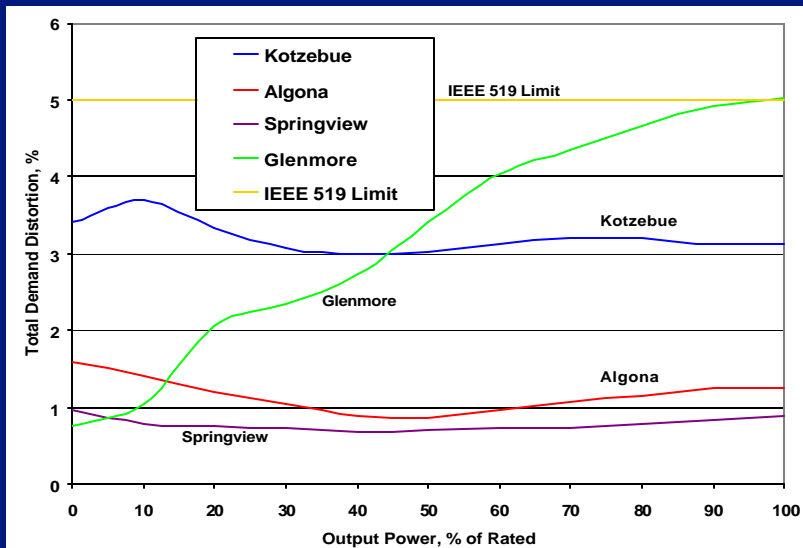
Feeder Voltage Regulation



Reactive Power



Current Harmonics



Utility Experience with Power Quality

- Wind turbines sharing distribution feeders with residential and commercial customers
- Proximity to sensitive loads: hospital and airport
- Over 100 % penetration on substations at times, 39% penetration for the entire Kotzebue grid
- No customer complaints in 2+ years of operation
- No operational problems due to power quality



References

- **Distributed Wind Power Assessment, NWCC, February 2001**
www.nationalwind.org/pubs/distributed/distributed_wind.pdf
- **Utility Wind Interest Group** www.uwig.org
- **Turbine Verification Program**
www.epri.com/targethigh.asp?program=207934&value=00T053.2&objid=197566



References (Cont.)

Individual TVP project Web sites

- Algona, IA www.netamu.com/WindFarm.htm
- Glenmore, WI www.wisconsinwindproject.com
- Kotzebue, AK www.kotzelectric.com/wind/wind_home.html
- Springview, NE www.nppd.com/aboutus/wind.asp
- **IEEE P1547 DRAFT Standard for Distributed Resources Interconnected with Electric Power Systems**
grouper.ieee.org/groups/scc21/1547
- **Making Connections:** Case studies of Interconnection Barriers and their Impacts on Distributed Power Projects
www.nrel.gov/docs/fy00osti/28053.pdf
- **DOE Distributed Power Program Web site:**
www.eren.doe.gov/distributedpower

